ART. VIII. — *Arago on Comets.*

1. *Des Comètes en Général et en Particulier de la Comète qui doit reparaître en* 1832 *et dont la Revolution est de* 6 *ans* ¾ 18mo. Paris 1831. Par M. ARAGO, Membre du Bureau des Longitudes.
2. *Des Comètes en Général et en Particulier de celles qui doivent Paraître en* 1832 *et* 1835. Par M. ARAGO, Membre du Bureau des Longitudes. 18mo. Paris. 1834.

THE present return of Halley's comet seems a fit occasion for some remarks upon this class of heavenly bodies, and upon that wonderful science which has revealed to us the secret mechanism of their motions. How different the impression now produced upon the public mind, from that which was manifested five revolutions ago, in 1456, when all good christians were solemnly called upon by their acknowledged head, the Pope, to curse the Comet together with the Turks, whose arms then threatened the subjugation of the fairest portions of christendom. We of the present day, have our eyes indeed directed to the same object, but with a state of mind how different? We are not taken by surprise; we are not alarmed at the novel spectacle; we were fully prepared for it, were expecting it almost impatiently; we had indicated the time when, and the spot where it was to make its first appearance; had traced among the stars, the path it was to describe; foretold the rate of its progress from day to day, and the general increase of its magnitude and brightness; when it was to be seen with the telescope, and when with the naked eye. All these minute particulars, and many more have long been before the world. They have been presented in every variety of form, adapted to the comprehension of different classes of readers. What a responsibility is thus assumed, on the part of those who have undertaken to make the future present? What confidence is thus manifested in the truth of those principles which have led to such astonishing predictions? With what a firm and unhesitating faith have these predictions been received? Who has doubted whether or not a comet would appear at this time, attended by those peculiar phenomena by which it has been distinguished? Is any one surprised at what has actually

occurred; that in every essential particular the prediction has been verified? It may be said, perhaps, that nine persons out of ten have not thought about the matter, and have given themselves no concern whether the comet made its appearance or not, or whether it conformed or not to what was foretold. But we would ask whence this indifference and unconcern? How happens it that men's minds are not now agitated as they were formerly? Who has taught us, that unusual appearances are no occasion for alarm and terror? That they are not to be regarded as symptoms of derangement or interruptions of established order, or tokens of the displeasure of the Almighty? Is not this absence of all anxiety and concern on the part of the unlearned one of the beneficial results, and not the least, which has attended the successful study of the stars? From year to year we are taught in our almanacs, which are perhaps more widely diffused than any other class of publications, not only the regular and stated occurrences of particular seasons, but rare and extraordinary events in the heavens, as eclipses of the sun and moon, the obscuration of a star or planet, and now and then the return of a comet to the sun, after long wandering in the remote regions of space. These predictions, accompanied as they are, with the minutest detail as to time, place, and circumstance, and followed as they have now been, for so many years, with the most exact fulfilment, have had an almost miraculous influence upon the public mind. The most illiterate are capable of appreciating this evidence, this undeniable and irrefragable proof of the high advancement of that science, which has thus enabled us to penetrate the future, and to forewarn mankind of events that are to come.

The history of this branch of astronomy, dates back only about two centuries. The accounts of comets that have come down to us from earlier times, although somewhat numerous, and in many cases relating to extraordinary celestial objects, are nevertheless so vague, and in all probability so exaggerated, as to be of little value. While the opinion prevailed, that comets were temporary fires lighted up in our own atmosphere, that is, of the same nature with those transient meteors that attract a momentary gaze and disappear, no exact observations were made, and no pains seem to have been taken to verify an hypothesis so hastily and generally received. It appears not a little strange to us of the present day, that it

did not occur to men so acute, and sagacious as Aristotle and others, who evidently had paid some attention to this subject, that meteors, and all atmospherical objects are to be seen only over a small extent of the earth's surface, and that they are seen in opposite directions from places not very remote from each other. The great meteor, for instance, which exploded over Weston, in the state of Connecticut, in 1807, seemed to be in a southwesterly direction, to persons in the neighborhood of Boston, whereas to a spectator near Philadelphia, it appeared in the opposite part of the heavens; and it was below the horizon, or wholly invisible, to persons situated at the distance of only a few hundred miles. Now it is very well known, that when a comet presents itself, it is not only seen over an extent of thousands of miles, but it seems to occupy throughout this region, the same place in the heavens. It appears in the same constellation, and near the same star. The path of the present comet, for instance, traced among the stars, is essentially the same to European and American observers. It is hence manifest, without having recourse to any exact observations, that comets cannot be very near the earth, as the ancient astronomers supposed; that they must be far removed out of our atmosphere even to the region of the planets. This important circumstance was first fully ascertained by Tycho Brahe; and being well established, it was sufficient of itself to overthrow the ancient doctrine on this subject. One reason, no doubt, why this crude opinion prevailed so long, was the belief in the existence of solid crystal orbs supporting the planets, and wheeling one within the other. The idea of large bodies, like what we now understand the comets to be, intersecting and traversing those solid spheres of crystal, was wholly inadmissible and irreconcilable with the received notions, touching the heavenly bodies; a striking example of the tendency of error to propagate itself.

Comets being thus recognised as very distant bodies like the planets, the next inquiry was to ascertain the paths they described, and the laws which govern their motions. The keen and penetrating eye of Newton was now directed to this subject, and comets at once assumed the dignity of planets, revolving round the same central body, describing the same kind of curves, preserved in their places by the same forces, subjected to the same laws, and differing only, or principally in this: that their orbits are more oval, or more elongated, and

lie in all manner of directions. This bold position was put to the test, in the case of the remarkable comet of 1680, which presented itself at this critical juncture, as if to vindicate this class of bodies of which it was so splendid a representative. The genius of Newton triumphed in this as in all his great enterprises; and comets now began to be regarded as an important part of the solar system. To put this rational and sublime theory beyond all question, and to convince the world of its truth, it was only necessary to identify a comet as one which had before appeared, or, in other words, to foretel the return of one of these bodies, and delineate beforehand its path through the heavens. This nice and difficult task was undertaken and accomplished by Halley. By comparing a comet which appeared in 1682, and which he saw himself, with one which was observed in 1607, they seemed to describe one and the same orbit.* It was not to be supposed that two comets would follow each other in identically the same path round the sun. It was fairly presumed therefore, that these were not two separate comets, but different appearances of one and the same comet; and that the interval between 1607 and 1682, or about 75 years, was the time employed to complete a revolution. This conclusion was rendered still more probable by going back about 75 years further, namely to 1531, when we find a comet described, that, from the observations that have come down to us, evidently pursued the same track through the heavens, which was described by that of 1607, and that of 1602. If any doubt remained of the identity of these comets, it must certainly be removed, when we are told further, that at another interval of the same length, that is to say, in the year 1456, there is a record of a comet whose path seemed evidently to correspond with those already referred to.

* An orbit is recognised to be the same with a former one, when it has in all respects the same position in the heavens, that is, when there is an agreement in the following particulars. 1. The *perihelion distance*, or distance of the point of nearest approach to the sun. 2. The position of this point or *longitude of the perihelion*. 3 The *inclination* of the plane of the orbit to the plane of the ecliptic. 4. The position of the intersection of these planes, or the *longitude of the node*. 5. The *direction* of the motion, whether from west to east like the planets or the reverse. The comet of 1682, for instance, had its orbit determined as follows;

Perihelion distance.	Longitude of the perihelion.	Inclination.	Longitude of the node	Direction.
0. 58 Sun's distance from the earth, being 1.	301° 36′	17° 42′	50°48′	Retrograde.

The following are the corresponding particulars for the comet of 1607.

0.58	302° 16′	17° 2′	50° 21′	Retrograde.

With such evidence before him, Halley ventured to infer that the comet of 1682 revolved round the sun, in about seventy-five or seventy-six years, and that consequently it might be expected to appear again, after the lapse of another such period. He accordingly had the courage and the good fortune to predict that this same comet would return towards the close of the year 1758, or the beginning of 1759. The time of a revolution seemed to be liable to considerable variation, which might be attributed, with great probability, to the attraction of the planets. To fix the time of the predicted return, as precisely as the nature of the case would admit, Clairaut undertook to calculate the effect which the larger planets, Jupiter and Saturn would have, in accelerating or retarding the motion of the comet, the result of which was, that the return of the comet to its perihelion, would be delayed by these two planets, about one year and eight months. The time fixed by Clairaut for the comet's reaching its point of nearest approach to the sun, was the 4th of April. He observed, at the same time, that he might err a month, by neglecting small quantities in the calculation. The comet was first seen near Dresden, by a peasant, on the 25th of December, 1758, thus verifying the prediction of Halley; and it passed its point of nearest approach to the sun, the 13th of March, 1759, within twenty-three days of the time fixed by Clairaut, for the perihelion passage, and accordingly falling within the assigned limits. The fulfilment of this memorable prediction, placed the theory of comets upon a sure basis. It has not only confirmed those who had entered into all the *a priori* reasoning upon the subject, but it was of a nature to carry conviction to the unlearned and the sceptical, to convert the mass of mankind, and make them firm believers, not only in the new doctrine respecting comets, but in the whole science of modern astronomy. A comet is no longer a meteor, a transient fire in our atmosphere. It is no longer a messenger of evil. It is no longer to be dreaded as a mysterious and unwelcome intruder among the celestial luminaries. It is to be ranked among the great works of nature. It is not only a curious object to behold, but it affords an interesting subject of contemplation. We delight to trace it through its long journey of three fourths of a century; and when the eye can no longer distinguish it, to follow it in imagination, as it pursues its upward flight, leaving planet after planet far behind, penetrating the unexplored depths of space, with an almost

inexhaustible force, and not ceasing its ascent, till it has doubled the distance of the most remote of the planetary bodies.

Other comets are at length found, as might be expected, to possess the character of revolving bodies. A comet appeared in 1818, which was recognised as one which had been observed several times before. Its orbit was of so small an extent, compared with that of most comets, as to admit of its period, or time of a complete revolution, being computed. This was ascertained by Encke, to be about three years and a third, and its return was predicted to take place in June 1822. Astronomers were apprised at the same time, that its situation in the heavens, would be such as to render it invisible in Europe and this country; but that it would be seen by the inhabitants of New South Wales. It actually returned according to the prediction; and after sufficient time had elapsed for intelligence to arrive from that quarter of the globe, we were greeted with a regular set of observations, made by Mr. Rumker, an experienced astronomer, at Paramata, completely justifying the anticipations of the sagacious Encke. This name has therefore already become familiar to us, like that of Halley, as a convenient means of designating a comet, with which we are continually becoming more and more acquainted, and through it, with the whole class to which it belongs. As it completes a revolution in about three years and a third, it has returned several times since 1822, namely, in 1825, 1828, 1832, and in the month of August of the year just closed. These frequent returns have been applied to a valuable purpose. They have served to teach us that the celestial spaces are in all probability not absolutely void, as we have been accustomed to regard them. There is the strongest reason for believing that this comet is resisted by an ether or some extremely rare medium. At each successive return, the evidence has accumulated, till at last the position assumed seems scarcely to admit of a doubt. The effect of the supposed medium has been, by checking the motion of the comet, in the direction of a tangent to its orbit, to cause the attraction toward the sun to predominate, whereby the path described is continually contracted into a sort of spiral, the time of a revolution at the same time being continually diminished. The amount of this diminution is found to be about two days each revolution, after making allowance, with all possible precision, for the disturbing influence of the planets. No other effect has been observed

to take place, after the most careful scrutiny, except that which would necessarily arise from the alleged cause.

Another comet is now supposed to afford additional evidence on this all important point, which gives an extraordinary interest, to each successive return of those comets whose periods are known. "It cannot be doubted," says Sir John Herschel, "that many more will be discovered, and by their resistance, questions will come to be decided, such as the following. What is the law of density of the resisting medium which surrounds the sun? Is it at rest or in motion? If the latter, in what direction does it move? Circularly round the sun, or traversing space. If circularly, in what plane? It is obvious that a circular or vorticose motion of the ether would *accelerate some comets and retard others*, according as their revolution was, relative to such motion, direct or retrograde. Supposing the neighborhood of the sun to be filled with a material fluid, it is not conceivable that the circulation of the planets in it for ages, should not have impressed upon it some degree of rotation, in their own direction, and thus may preserve them from the extreme effects of accumulated resistance."*

Another comet, known as Biela's, appeared in 1826. It is recognised as being the same which was observed in 1805 and in 1772. It was found to have a period of six years and three quarters. Its return was accordingly predicted to take place in October, 1832; and it actually made its appearance at the time and place assigned. It is remarkable for its near approach, not to the earth itself, but to the earth's orbit, the least distance being less than the sum of the semidiameters of the comet and the earth, so that if the earth had happened to be in that point, at the same time with the comet, it would certainly have been involved, to a greater or a less degree, in the nebulous matter of the comet. The earth, in fact, reached this point, a month later than the comet, and did not, at any time, come within about fifty millions of miles, or half the distance of the earth from the sun. This comet, at its greatest distance from the sun, departs about six times the earth's distance, or somewhat beyond the orbit of Jupiter. Its next return will take place in 1838.

It is thus abundantly proved that comets are revolving bodies like the planets, and that they obey the same great laws of at-

* Herschel's Astronomy, Art. 484. Note.

traction. There seems, notwithstanding, to be a marked difference in their physical constitution. Comets appear to be composed of a substance extremely light compared with that of the planets. Thus Halley's comet which, as we have seen, was detained a year and eight months by the attraction of Jupiter and Saturn, seems to have had little or no reciprocal influence upon either of these planets. A still more striking instance to the same purpose, occurs in a comet which appeared in 1770, which, according to the highest authority, had been revolving in an orbit that did not admit of its being seen from the earth, completing a revolution in about fifty years; but passing in 1767 within a short distance of Jupiter, its course was entirely changed, so as to bring it near to the earth in 1770, and cause it to complete one revolution about the sun in the short period of about five years and a half. Coming near to Jupiter a second time, in the remote part of its course, its orbit is again shifted to one requiring a period of about twenty years. In one of these cases the comet is proved to have passed so near to Jupiter, that its attraction to this planet was two hundred times greater than its attraction to the sun. Still, it not only had no sensible effect upon the planet itself, but it did not even disturb the motion of its satellites, although it passed between them and the body of Jupiter.

This comet came nearer to the earth than any other whose path is known. Its least distance was about six times that of the moon. It was retarded in consequence, about two days, by the earth's attraction. If the comet had the same quantity of matter with the earth, it must have affected the length of our year to the amount of nearly three hours; but it did not exert the least perceptible influence. If the year had suffered an alteration to the amount of two seconds, it would probably have been detected. It is hence inferred that the quantity of matter contained in this comet could not exceed the five thousandth part of that contained in the earth.

What is here stated with respect to the lightness of comets, agrees very well with the result of actual observation. Many comets have appeared that seem to be destitute of any nucleus or solid, compact mass at the centre. They are apparently composed of a matter resembling the thinnest vapor, so that the light of the faintest star which is obscured by the least perceptible fog, scarcely suffers any diminution by penetrating many thousand miles of this substance. The comets of Encke

and Biela, and some others, seem to be thus constituted. In those cases where there are signs of a solid nucleus, it is for the most part of small extent. It has been estimated in two instances at less than thirty miles in diameter. The comets of 1807 and 1811 were supposed by Sir W. Herschel to have each a diameter of about five hundred miles.

Even where there is the appearance of a compact mass at the centre, there is still surrounding it, the same nebulous appearance of vast extent, which seems to constitute, in other cases, the whole matter of the comet. This nebulous appearance, instead of being of a uniform or a progressively increasing brightness from the circumference inward, is often apparently composed of one or more rings or strata, many thousand miles in thickness, alternating with fainter portions, an appearance not unlike what would be presented to a spectator viewing from a distance our earth with its different layers of clouds, one above another separated by portions of transparent atmosphere.

A remarkable circumstance has been observed in two or three instances, which consists in the great contraction of the body of the comet as it approaches the sun. Encke's comet was carefully examined at different distances from the sun, varying from about one hundred and fifty to fifty millions of miles. In the former case, its diameter was twenty-five times as great as in the latter, and its bulk, of course, was reduced to about one sixteen thousandth part by a reduction of its distance to one third part. This enormous change in its dimensions, has been ascribed by some, to the varying density of the sun's atmosphere, the gaseous matter of the comet, being, as is supposed, more and more condensed as it penetrates the denser strata of this supposed medium, just as a balloon is enlarged or contracted, according as it is situated in a denser or rarer part of the earth's atmosphere. Others suppose, that as the parts of the nebulous matter of the comet are distant, and held together by so feeble a power, they revolve in a degree independently of one another, each having its own perihelion, whereby they are brought nearer to each other, as they approach the sun, and separate again farther and farther as they depart from it. Another hypothesis is that the nebulous matter of the comet, like fog or common vapor, which disappears before the rising sun, ceases to be visible, in like manner, as the comet approaches its perihelion, in consequence of the heat to which it is exposed, and that it is restored to its sensible form, when it is sufficiently withdrawn from the influence of the solar rays.

But the most obvious and striking characteristic of comets, especially to the majority of observers, is the luminous train, called the *tail*, with which they are generally attended. We say generally, since this is not by any means a constant appendage. Many comets have appeared, as those of Encke and Biela, that seemed to be as round as the planets. Others again, as the present comet for instance, have exhibited a train only in certain parts of their course and not in others: sometimes it is visible only in certain parts of the earth, and in certain states of the atmosphere. Where it exists at all it seems to increase as the comet approaches the sun, and to be more conspicuous, and of greater extent after the comet has passed its perihelion than before. It is also remarked that the direction of this luminous train is, for the most part, in a line opposite to the sun. There are remarkable exceptions, however to this rule. It is found in some instances, to be at right angles to a line joining the comet and sun.

In its common position the train is often curved more or less, the extreme parts being left as it were a little behind, while the preceding or convex portion is observed to be somewhat brighter than the rest, as though there were some rare medium which condensed the luminous matter and slightly impeded its motion.

Where the train is not curved, it is often remarked that the light is faintest in the middle and strongest towards the edges, as though it were a hollow cylinder, or truncated cone. The tail is sometimes divided into two or more branches, lying in some cases the same way, but often more or less inclined to each other. The comet of 1744 had six tails, opening and diverging like the sticks of a fan, but curved at the same time like a sickle. They were each about 4° broad, and from 30° to 44° long. The light was so strong, that they were distinctly perceived after the sun rose.

Single trains have been observed of all lengths less than 100°. The absolute lengths have been computed in many instances, and found to vary from a few millions to one hundred millions of miles.

Nothing that deserves the name of an explanation has yet been offered, respecting the constitution and manner of production of this curious phenomenon. The hypothesis most in vogue, is that which ascribes it to the mechanical impulse of the solar rays, penetrating such an extent of vaporous matter very feebly held together by the small central attraction; just

as a discharge of shot through a mass of cotton or eider down may be supposed to carry a portion of this light substance with it, to different distances. This notion is of course wholly inapplicable to those cases where the luminous train does not lie in the direction of the sun's rays. It is, moreover, less entitled to consideration, now that light itself, instead of being an emanation of particles, is beginning to be more generally considered, as depending upon the undulation of a medium, which medium may be that very ether indicated by Encke's comet, as already mentioned.

It seems to be taken for granted, that this train is a material substance, and that this substance is of the same nature with the nebulous atmosphere of the comet; and that it once made a part of that atmosphere. But how is it separated and borne along to such enormous distances? What power retains it, and keeps it in its relative place, when, as it should seem, the attraction exerted by such an inconsiderable mass as that of a comet, is wholly insufficient? What should cause the extremity of the tail, to move ten or twenty times as fast as the comet itself, when it is so many times farther from the sun, as it must do in order to keep the same position with respect to the central body? If it is said in reply, that it is perpetually renewed by every new emission of solar light, we beg leave to ask what becomes of these long trains, when they have served their momentary purpose, and why should they not continue to reflect the light that falls upon them, long after they have been generated? thus producing a broad luminous tract throughout the space over which the tail has swept.

It is indeed, generally admitted, that more or less of the luminous train is left behind, and wholly detached from all connexion with the body, whence it proceeded. This is rendered probable, not only for the reasons above suggested; but also from the fact that in several instances this appendage is found to become shorter and shorter, and less and less conspicuous, at each successive return. Not only the train, but the body of the comet seems to be wasting away, as in the case of Biela's, which at its last return could scarcely be discerned with a good ten feet telescope, in the most skilful hands; and was actually invisible to the inhabitants of this continent; for want of sufficient aid to the natural sight.

If comets are thus destined to part with the matter of which they are composed, and the celestial spaces are continually

strewed with this highly rarified, and all but immaterial substance, we have arrived at a probable source of that medium, which seems to have been detected by the motions of Encke's comet. We may remark also, that the substance surrounding the sun, and lying in the direction of its equator, and extending many millions of miles, giving rise to what is called the *zodiacal light*,* may have the same origin, that is, may be composed of the tails of innumerable comets.† Indeed, the sun itself may be said to have a tail or train extending in opposite directions, borrowed, perhaps, by little and little from each passing comet; and this train may in some degree resemble that of a comet, and be a conspicuous object to a spectator situated in such a manner as to admit of its being seen unmixed and unobscured by the light of his own atmosphere.

It will be inferred, we are aware, from what we have said, that comets may, by slow degrees, be dispersed through the celestial spaces and absorbed into the sun's atmosphere, and thus cease to be comets any longer. There is also another way in which they may terminate their existence as comets. This very medium, this solar atmosphere, strewed with the wreck of we know not how many of these ill fated bodies, seems fitted to prove destructive to many more. Encke's comet, by its short period and frequent returns, affords the best opportunity hitherto presented, of judging of the consequences that must result from such a state of things. This comet is evidently approaching nearer and nearer to the sun, each revolution. There is no cause known to astronomers, that can save it from its impending fate; and hereafter, when we shall have become familiar with the return of comets, and are well acquainted with their diminishing periods, it may become an object of emulation to astronomers, to calculate and foretell the time when a comet shall terminate its career by falling into the sun. The comet of 1680 has already approached so near as to be only one sixth of the sun's diameter distant when in perihelion.

* This light is of a pyramidal or leaf-like shape, having the sun for its basis and the ecliptic, or rather the solar equator for its axis, or line of direction. It is faint like the tail of a comet, or the milky way, and is for the most part confounded with the twilight, except in low latitudes, where it is more frequently seen. But in the month of April, in the evening, or in October, in the morning, it makes so large an angle with the horizon in the temperate latitudes, and extends so high, that it may be seen after the twilight has ceased in the evening, and before it begins in the morning.

† Herschels's Astronomy, Art. 626.

It appeared in Newton's time, and no doubt seems to have existed in the mind of that great man, that it would at some future epoch, cease to revolve. This opinion he retained to the latest period of his life, and he seems to have made some estimate of the time that might be expected to elapse before such a catastrophe would take place; "possibly" he says, "after five or six revolutions."

This idea of the destiny of comets, that they were designed ultimately to fall into the sun, and be consumed, was the more readily received formerly, when the sun was regarded as a mass of ignited matter, that required replenishing like our domestic fires. Light itself, moreover, being supposed to be an emission of particles, it seemed to be necessary to find some means of supplying this continual exhaustion of the sun's substance. Other and more remote phenomena were referred to as strikingly analogous to the case in question. Several of the fixed stars had, at different times, suddenly burst forth with great splendor, so as to surpass even Jupiter and Venus, and in some instances to be visible in the day time. These stars, it was supposed, owed their increased brilliancy to a fresh supply of fuel in the form of a precipitated comet. Such are the conjectures and speculations of some of the greatest men the world has produced.

But among astronomers of the present time, who allow this tendency in cometary bodies toward the sun, without being able to point out any sufficient check, some maintain that matter so exceedingly rare, and indeed matter of any kind and of any form with which we are acquainted, must in all probability be completely volatalized by the solar heat, and absorbed into the solar atmosphere, long before it could reach the body of the sun. It is believed that some comets already give indications of a rapid approach to this sort of dissolution.

Another fruitful subject of speculation relates to the possibility or probability of a comet's coming so near the earth, as to occasion a great revolution in the physical condition of our globe. The nearest approach of one of these bodies that has hitherto taken place, so far as our knowledge extends, was that of the comet of 1770, as already mentioned. The least distance, in this case, was no less than 1,456,840 miles. No effect upon the earth or moon was perceived, although an exceedingly slight one, if it had existed, must have been detected.

A much nearer approach than this, is liable to take place, from the known position of the orbits of other comets whose elements have been calculated. The great comet of 1680, so remarkable in other respects, is also distinguished as coming near to the earth's path. Its least distance is about twice that of the moon, or 440,000 miles. Its attractive force, therefore, would be only one fourth of that of the moon, on the supposition that it contained as much matter. Even this force would be exerted only for a short time, not long enough, probably, to produce any sensible disturbance in the waters of the ocean. The effect of the moon in causing the tides, is the accumulated result of a long continued effort, with comparatively little change in the position of the attracting body, or the direction of its action. With all the force that the moon actually exerts, it would have very little, if any, sensible influence in disturbing the ocean, if it were to dart by us with the rapidity of the comet under consideration.

Biela's comet has already been described as coming so near the earth's track, as to be liable actually to involve a part of the earth at least, in its nebulous atmosphere. Let us now see what chance there is of the earth's being, for instance, within half a million miles either way, of the particular point of danger. There being in the circumference of the earth's orbit six hundred millions of miles, in round numbers; on the supposition that the comet passed the point in question, once a year, there would be an equal chance for each portion of a million of miles, that the earth would be there at that juncture; of course, according to the doctrine of chances, the earth may be expected to be within half a million of miles of the point under consideration, once in six hundred years, it being supposed that the comet passes this point once a year. But as it actually passes it only once in six years and three quarters, the above period must be increased in the same proportion; that is, the near approach of the earth and comet, above referred to, cannot be supposed to occur more than once in about forty centuries.

Allowing the possibility of the event in question, what would be the probable consequences of a near approximation, or even a rencountre? Not, so far as we can judge, a violent shock or concussion, like that occasioned by one vessel running against another, not a sudden and overwhelming rush of the waters of the ocean over the land. This comet of Biela, according to the best information we possess, seems to be merely

a collection of the thinnest possible vapor. Let us imagine a person in a balloon approaching a cloud. The object might seem a formidable one; but the æronaut is plunged in the vaporous mass before he is aware of it. He is sensible of no material change; he has felt no jar. He only perceives a little obscurity in the objects around him, and wonders what has become of the cloud that seemed so menacing in the distance. So it may be with regard to comets. We may have already encountered one of these bodies without ever dreaming of it. We may have been enclosed in its vast envelope without perceiving any change, except, perhaps, some peculiar hue in the atmosphere, or some uncommon tint in the objects about us. We are passing frequently through parts of space that have, in all probability, been visited by the enormous train of some comet, and which, we have reason to believe, still retain traces of this substance. It is hardly possible to conceive that the earth should have escaped all contact with an element so widely diffused, or that it should fail to attract and appropriate to itself some portion of this matter. We see the zodaical light, supposed to be identical with the substance in question, embracing the orbits of Mercury and Venus, and of course enveloping these planets, and mixing with their atmospheres, and subjecting them to all the consequences that we seem to dread from the introduction of matter so foreign. There is little reason to believe that the earth is exempt from the same lot, and little ground to apprehend evil from a condition that seems the necessary result of the original constitution of the system to which we belong. What the tail of a comet is, it were vain to conjecture. Some future chemist may perhaps tell us. But whatever it be, whether watery vapor or any other vapor, or one of the permanent gases, or something different from all these, and wholly unlike any of our aëriform substances, there is little reason to suppose that it would, on the whole, be injurious. Even if it were deleterious in itself, if it were the most virulent poison, still, according to all that we know of it, it is so exceedingly rare, and would constitute so very small a proportion as an ingredient of the air we breathe, that no evil could be apprehended from it. The fixed air and other noxious gases, that are disengaged by volcanoes and discharged into our atmosphere, may often be found to exist in much greater quantity, compared with the vital principle, especially in the vicinity of the volcano, than we are liable to be exposed to, from the lar-

gest influx from a comet's train. Such an accession of matter to our globe, although it is believed to have actually taken place, perhaps more than once, has not as yet, been distinctly and satifactorily recognised. There are several instances on record, of a peculiar state of the atmosphere, that has been ascribed to the presence of matter from this source. The following are Mr. Arago's statements and reasoning upon this subject.

"The fog of 1783 began nearly on the same day (the 18th of June) in places very distant from each other, as Paris, Avignon, Turin, Padua;

"It extended from the northern coast of Africa to Sweden; it was also observed in a great part of North America;

"It lasted more than a month;

"The air, at least that of the lower regions, did not appear to be its vehicle, because in some places it came on with a north wind, and in others with a south or east wind;

"Travellers found it on the highest summits of the Alps;

"The abundant rains which fell in June and July, and the highest winds, did not disperse it;

"In Languedoc, its density was occasionally so great that the sun did not become visible, in the morning, till it was 12° above the horizon; it was very red the rest of the day, and might be looked at with the naked eye.

"This fog or smoke, as some meteorologists have called it, had a disagreeable odor.

"The property by which it was particularly distinguished from common fogs, was its being, by all accounts, very dry, whereas most fogs are moist. At Geneva, Sénebier found that the hair hygrometer of Saussure, which in real fogs stands at 100°, ranged in the midst of this, as low as 68°, 67°, 65°, and even 57°.

"Besides all this, there was one very remarkable quality in the fog or smoke of 1783; it appeared to possess a phosphoric property, a light of its own. I find, at least in the accounts of some observers, that it afforded, even at midnight, a light which they compare to that of the full moon, and which was sufficient to enable one to see objects distinctly at a distance of two hundred yards. To remove all doubts as to the source of this light, it is recorded that at the time there was a new moon.

"Such is the state of the facts; let us now see whether, in order to explain them, it will be necessary to admit, that in 1783 the earth was immersed in the tail of a comet.

"The fog of 1783 was neither so constant, nor so thick, as to prevent the stars being seen every night, in all the places where it occurred. Admitting therefore that the earth was in the tail

of a comet, there is but one way of explaining why the head of that comet was never seen, and this is, by supposing, that it rose and set almost at the same time with the sun; that the superior light of that luminary rendered it invisible; and that this conjunction of the sun and comet lasted more than a month.

"At a time when the proper motions of comets appeared subject to no rule, when every one disposed of them as he pleased, considering them as mere meteors, the supposition we have just made might be admitted; but now that comets are known to all astronomers to be heavenly bodies, as obedient as the planets to the laws of Kepler; now that the mutual dependence of distance and velocity is known; now that observation and theory combine to prove that all these bodies *necessarily* move in their orbits with a rapidity that increases as they approach the sun, it would be contrary to all established principles to admit that a comet, interposed between the sun and earth, could revolve about the sun in such a manner as to appear constantly near it for more than a month, to a spectator on the earth! It is in vain to attempt to explain the difficulty attending an exact conjunction, by supposing the tail very large. If it were as large as that of 1744, the objection would remain in all its force. The dry fog of 1783, then, whatever may have been said of it, was not the tail of a comet." — pp. 88—91.

A dry fog, similar to the one above described, was noticed in different quarters of the globe, in 1831. It was observed on the coast of Africa on the 3d of August, in the south of France on the 10th, and at New York on the 15th of the same month. This fog was so thick, that the sun might be looked at all day, without any colored glass or other protection to the eye; and, in some places, the sun remained invisible till it had risen 15° or 20° above the horizon. When clearly seen, it was often remarked, that the color was changed to an azure blue, and sometimes to greenish or emerald green. At night the heavens occasionally became clear, so that the stars could be seen.

Where this fog was observed and while it continued, there was a very unusual degree of light during the night. In Siberia, at Berlin, and at Genoa, in the month of August, the smallest writing could sometimes be read even at midnight.

This phenomenon, however, was not general, even in Europe. At Paris and some other places, it was but faintly perceived, and for a few days only. If a comet, therefore, had passed at this time, between us and the sun, no reason can be given why it was not seen. We are hence obliged to conclude,

as in the former case, that the fog was not attributable to a comet.

The following are the remarks of our author upon the agency which this extraordinary fog is supposed by some persons to have had in the uncommon pestilence which made its appearance in Europe, about the same time.

"Many authors have chosen to see some connexion between the extraordinary fog of 1831 and the entrance of the *cholera morbus* into Europe. This opinion reminds me of what an old English traveller, Matthew Dobson, says of the effects of a periodical wind on the west coast of the continent of Africa, which is called the *Harmattan*. On reading over the original narrative just as I was about to send these pages to the press, I was so struck with several points of resemblance between the properties of the air, where this wind prevails, and that which is filled by the dry fogs of Europe, that I determined to give here a short analysis of that memoir. The reader will observe, that out at sea, some distance from the shore, the Harmattan loses its peculiar qualities; and he will remember, that in 1783 the dry fog was not perceived in the middle of the Atlantic, although it darkened at the same time the atmosphere of Europe and America. He will see also, that all fogs of this description are not fatal.

"A wind that blows three times each season from the interior of Africa to the Atlantic Ocean, is call the *Harmattan*. On that part of the coast which lies between Cape Verd (Lat. 15° N.) and Cape Lopez (Lat. 1° S.), the Harmattan is chiefly felt in December, January, and February. Its direction is between E. S. E. and N. N. E. It commonly lasts two days, sometimes five or six. It is always a moderate wind.

"A *fog* of a particular kind, and thick enough to impede at noon all but the red rays of the sun, always presents itself where the Harmattan blows. The particles, of which this fog is formed, are deposited on the grass, on the leaves of trees, and on the skin of the negroes, in such profusion as to produce a white appearance. Of the nature of these particles we are ignorant; we only know that the wind carries them but a short distance from the shore. A league out at sea the fog is much lighter; and, at the distance of three leagues, it disappears entirely, although the Harmattan is still felt in all its force.

"The *extreme dryness* of the Harmattan is one of its most striking characteristics. When it lasts some time, the branches of orange and citron trees die; the covers of books (even when they are shut up in tight trunks, and have additional covering of linen,) warp as if they had been before a large fire. Pannels of doors, window-shutters, and articles of furniture crack and often

break. The effects of this wind upon the human body are not less remarkable; the eyes, lips, and palate become dry and painful. If the Harmattan last four or five days together, the skin of the hands and face comes off; to prevent this, the natives rub their bodies all over with grease.

"After what has been said of the fatal effects of the Harmattan on vegetables, it may be thought that this wind *must be very unhealthy*, whereas quite the contrary is observed. Intermittent fevers are completely cured by the first breath of the Harmattan. Patients reduced by the excessive bleeding practised in that country, recover their strength; remittent and epidemic fevers also disappear, as if by enchantment. Such is the salutary influence of this wind, that, while it lasts, infection cannot be communicated even artificially. This assertion rests upon the following fact:

"In 1770, there was an English vessel at Wydah, called the *Unity*, which was loaded with three hundred negroes. The small pox having appeared among some of them, the owner determined to inoculate the rest. All who were thus operated upon, before the Harmattan began to blow, took the infection. Seventy were inoculated the second day after that wind began to blow, and not one of these had the disease, or the least eruption. However, some weeks afterwards, when the Harmattan no longer blew, these very persons took the disorder. It is also added, that during the second appearance of the malady, the Harmattan began to blow again, and sixty-nine slaves, who had it, all recovered.

"The country over which this remarkable wind passes before it reaches the coast, is for two hundred and forty miles, composed of verdant plains, entirely open, some woods of small extent, and here and there a few rivers and inconsiderable lakes.—pp. 99—103.

Other disasters and indeed all sorts of malign influences, have been attributed to comets by authors every way entitled to respect; and this has been done without taking the trouble to assign any definite cause for effects of so various a character, or to point out any connexion whatever, depending upon the known laws of the world we live in. Mr. Arago, of course, espouses the cause of comets, and maintains their innocence to our entire satisfaction. We have room for only a few quotations, with which we close the present article.

"An English physician, whose name is not unknown to philosophers, Mr. T. Forster, has lately treated particularly of this subject. According to him, '*It is certain*, that ever since the Christian era, the most unhealthy periods are precisely those in which

some great comet has appeared; that the approach of these bodies to our earth has always been accompanied by earthquakes, eruptions of volcanoes, and atmospheric commotions; whereas, no comet has ever been seen during the salubrious periods.'

"Those who will take the pains to examine critically the long catalogue, given by Mr. Forster, will not, I am sure, be led to the same conclusions.

"The whole number of comets mentioned by historians, reckoning from the beginning of the Christian era to the present time, is about five hundred. At the present time, when the heavens are examined attentively and skilfully, when comets that can be seen only by the aid of the telescope are no longer overlooked, the average number of these bodies is more than two for each year. If we agree with Mr. Forster, that their influence begins before they are visible, and continues some time after, we shall never be without a comet to account for every phenomenon, misfortune, or epidemic that can occur. This remark is applicable also to the Memoirs of the celebrated Sydenham, who was an advocate for the influence of comets; to the dissertations of Lubinietski, &c. Mr. Forster has moreover, I ought to say, so extended, in his learned catalogue, the influences of comets, that it would seem there is scarcely a phenomenon which is not to be ascribed to them.

"Hot and cold seasons, tempests, hurricanes, earthquakes, volcanic eruptions, violent hail-storms, great falls of snow, heavy rains, overflowings of rivers, droughts, famines, thick fogs, flies, grasshoppers, plague, dysentery, contagious diseases among animals, &c., are all registered by Mr. Forster, as consequences of the appearance of some comet, whatever may be the continent, the kingdom, the town, or the village so visited. By thus making out for each year a complete catalogue of all the miseries of this lower world, any one might foresee that a comet would never approach the earth, without finding a part of its inhabitants suffering under some calamity or other.

"By a strange accident, well worthy of remark, the year 1680, the year of the most brilliant of modern comets, the year of its passage so near the earth, is that which has furnished our author with the fewest phenomena. Let us see what is to be found under this date? '*A cold winter, followed by a hot and dry summer; meteors in Germany.*' As to maladies, we find no record whatever! How then, with such a fact as this before us, can we attach any importance to the accidental coincidences noted in other parts of this table? How are we to regard this celebrated comet of 1680, which, blowing now hot and now cold, increased the frosts of winter, and the heat of summer?

"In 1665, the city of London was ravaged by the plague. If, with Mr. Forster, we attribute this to the remarkable comet which

appeared the same year, in the month of April, how are we to explain why the same pestilence did not extend to Paris, to Holland, to any of the numerous towns in England except the capital? This difficulty must be met; and until it is done away, we shall expose ourselves to the ridicule of every man of sense, if we attempt to make comets the messengers of evil.

"Let us now see which are the comets whose tails may have mingled with the earth's atmosphere; and then search the histories and chronicles of the same period, to discover whether, at the same time, there were not manifested, *in all parts of the earth at once*, unusual phenomena. Science may take note of such researches; though, to tell the truth, the extreme rarity of the matter which composes the tail, would lead one to expect nothing but negative results; but when an author appends to the date of a comet, like that of 1668, the remark that *all the cats in Westphalia were sick;* and to the date of another, that of 1746, the circumstance, very little analogous to the former, to be sure, that an *earthquake* destroyed in *Peru* the towns of Lima and Callao; when he adds that, during the appearance of a third comet, a *meteoric stone* fell in *Scotland*, into a high tower and broke the wheels of a clock; that, during the winter, wild pigeons appeared in large flocks in *America;* or still more, that *Ætna* or *Vesuvius* threw out torrents of lava, — we must consider him as displaying his learning to little purpose. If, in thus registering contemporary events, he thinks he has established some new relations between them, he is as much mistaken as the old woman, mentioned by Bayle, who, never having put her head out of her window without seeing coaches in the Rue St. Honoré, imagined herself to be the cause of their passing.

"I wish, for the honor of science, that I could have dispensed with taking any serious notice of the ridiculous ideas I have just adverted to; but I am satisfied that this exposition will not be without use, for Gregory, Sydenham, and Lubinietski have many followers among us.

"Moreover, if you will only listen, in those circles which are called fashionable, to the long discourses of which the approaching comet is the theme, you may decide whether there is any room to congratulate ourselves upon the pretended diffusion of knowledge, which so many *perfectionists* are pleased to consider as the distinguishing feature of our age. For myself, I have long been cured of these illusions. Under the brilliant but superficial gloss, with which the purely literary studies of our colleges cover all classes of society, we almost always find, to speak plainly, a profound ignorance of those beautiful phenomena, those grand laws of nature, which are our best safeguard from prejudice."— pp. 82—87.